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ABSTRACT

Twenty-four profoundly deaf children (7 to 13 years old) from a residential school were presented with conservation problems of liquid, matter, weight, and volume. Analyses of variance showed that age was significant beyond the .01 level and type of task (conservation) at the .25 level. No significant sex effect was found. Differences among means were computed and suggested the following order of acquisition: volume-matter-weight-liquid. This order was in disagreement with the order established by J. Piaget with nonhandicapped children; and, in regard to volume, significantly different from the order established by Affolter with deaf children. The developmental reversal of both liquid and volume, the two forms which are acquired approximately 5 years apart in hearing children, seriously weakens H. Furth's position that deaf and hearing children do not essentially differ regarding cognitive development and his argument regarding the relationship of language and cognition during the concrete operational stage of development. (Author)

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DEAF CHILDREN'S JUDGMENTS ON CONSERVATION PROBLEMS OF LIQUID, MATTER, WEIGHT AND VOLUME: A PILOT STUDY

Robert K. Rittenhouse, Ph.D.
Assistant Professor
Department of Special Education

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Overview

To say that a quantity is conserved under transformations of pouring or deformation is to mean that these transformations leave quantity unchanged--that the quantity is equal to what it was before it underwent the transformation (Elkind, 1969). Tests of conservation are considered valid measures for determining the presence or absence of the concept of reversibility. In Piaget's theory of cognitive development, the ability to mentally undo an operation (reversibility) marks the pivotal stage in a child's thinking from that of pre-logical to logical reasoning (Flavell, 1963).

Classically, conservation of quantity starts with the presentation of two distinct collections of equal amounts of material (two rows of beads, two vessels of liquid, two lumps of clay, etc.). First the child is encouraged to establish their quantitative equality ("Is there as much to drink in this one as in that one? Do we both have the same?"). Then he observes one of the collections undergo a transformation (stretching, compressing, pouring into a vessel of different dimensions, etc.) that changes some of its perceptual features while maintaining its quantity. Finally, the child is asked to judge the relative quantity of the two collections after the transformation. To be classified as "having conserved," he must be able to assert that the quantities are equal and give an adequate explanation as to why they remain invariant (Klahr and Wallace, 1973).

Problems of conservation take several forms and the presence of conservation on one form doesn't assure its presence on the others (Hall and Kingsley, 1968). In fact, evidence indicates that conservation is developmental and that the order of acquisition for four of the forms is: liquid

(ages 5-7), matter (8-10), weight (10-12) and volume (after age 12) (Flavell, 1963). These four forms represent a continuum across practically the full range of the concrete operational stage of development.

The purpose of this study was to determine if this order of acquisition was the same for deaf children. Piaget (1966) reported the results of a pilot developmental study carried out by F. Affolter using deaf subjects. In the study, the order of attainment was matter (8years), weight (9 years), volume (11 years) and liquid (11 1/2 years). Furth (1966) also found that conservation of liquid was apparently the most difficult form of conservation for deaf children to acquire. Piaget (Flavell, 1963), in an experiment with 180 hearing children aged 4-10 years, found that such developmental reversals (e.g., conservation of volume achieved before conservation of liquid) were rare or absent.

Also of interest to the present writer was the pattern of behavior of non-conservers. Were they likely to rely on the available perceptual information and make non-conservation responses? According to Piaget (1967; 1970), a non-conserving child will initially center on either length or height or width. As the transformations are continued, he will switch his focus to the other attribute. Miller (1973), however, has found that most non-conservers think that length or height properly defines amount. They maintain this belief over several problems regardless of the number or order of the transformations. Of particular interest to the present writer was the strength of the perceptual information: would deaf children be perceptually bound and thus make nonconservation responses or could they overcome this "illusion" and recognize the quantities as equal?

Review of the Literature

In administering problems of conservation, experimenters have employed several modifications of Piaget's standard procedure. Because of these variations, one focus of this section will be on those procedures. In addition, the order of acquisition of liquid, matter, weight and volume in deaf and hearing children will be ascertained.

The order of these four forms has been well established in non-handicapped children (Elkind, 1961; Flavell, 1963) and blind children (Gottesman, 1973; Hatwell in Gottesman, 1973). Elkind (1961b), in one of two successive experiments with non-handicapped children, found that conservation of liquid was present between ages 6-7. In the other experiment (1961a), conservation of matter was established at age 9, weight at age 10 and volume at age 11. This closely approximates Piaget's (Flavell, 1963) earlier finding: conservation of liquid becomes common at age 5-7, matter at 8-10 years of age, weight at 10-12 and volume at 12 years and after.

Because Elkind's two conservation studies (1961a; 1961b) were replications of Piaget's earlier work, the procedures will be detailed in order to illustrate one of Piaget's standard procedures. In Elkind's (1961b)

While the procedures for administering Piaget's tests for conservation differ somewhat (e.g., some experimenters do not ask the S to make a prediction prior to the transformation; some Es make several transformations for each conservation form), it is required that, in order to be considered a conserver, the subject must be able to adequately explain his conservation response ("They were the same when you began; one is tall but thin, the other is short but fat so they are the same."). However,

Furth (1964b), in a study of the conservation of weight in deaf children, presented a 13-step problem which included 9 transformations and required no conservation explanations of the subjects.

Steps 2, 8 and 9 were considered the essential trials for the principal of conservation. At these steps, the subjects made a judgment regarding the weight relationship between two clay balls of different shapes (ball vs. snake; ball vs. ring; disc vs. ring). Prior to these judgments (Step 1 and Step 7) the equality of the two balls of clay was established and one ball was then deformed. All steps had items of equal weight except steps 3, 6 and 12 which were introduced as control steps so that a "same" response would not always be correct. The subjects were aware that the two items were not of equal weight. For example, at step 3, a snake (transformed from a ball) was compared to half a ball. Furth found that even after eliminating verbal explanations of judgments, the deaf subjects lagged significantly behind the hearing subjects (at the 8-year level it was found that 45% of the deaf children and 90% of the hearing children satisfied the criterion of success). The 6 year old hearing subjects, however, were equal in performance to the 8 year old deaf subjects, with 41.1% of the group succeeding.

In summary, experiments of conservation with blind and sighted, non-handicapped children show the order of acquisition to be: liquid, matter, weight and volume; and with deaf subjects to be: matter, weight, volume and liquid. Blind children tend to lag 2-3 years and deaf children 2-6 years behind sighted, hearing children. Procedures vary from Piaget's 3-step method of first asking subject to predict what amount will be following a transformation, making the transformation and asking subject to make a judgment and finally eliciting a response from subject regarding the

judgment to Furth's 13-step method where no prediction or verbal explanation is required and subject must make judgments following several transformations.

Statement of the Problem

It has been apparently established that conservation does not emerge all at once not only in non-handicapped children but in deaf children as well. The apparent order of acquisition for deaf children has, however, been arrived at by piecing together several independent studies (Furth, 1964: Oleron and Herren, 1961; Affolter in Piaget, 1966). These experiments have been conducted at various points in time over a five year period, using deaf subjects with different characteristics, and employing quite different experimental procedures. As a result, there is obvious disagreement over the difference between the rate of acquisition for deaf and hearing children. In addition, conservation of liquid, which is established early in hearing children, seems to be the most difficult form for deaf children to acquire.

Furth (1970) argues that the sequence of cognitive development in deaf children does not essentially differ from that of hearing children. Because of the language disability of pre-lingually deaf children, Furth views this pattern of their development as supporting evidence of the Piagetian position regarding the independence of language and thought prior to formal operations. A single experiment, in which the order and age of acquisition can be determined, will allow not only for comparisons between the cognitive performance of deaf and hearing children to be made, but might also provide new or additional evidence regarding this theoretical position on language and thought.

Hypotheses

It is predicted that these 4 conservation forms will not all come at once. One of two outcomes seem likely: 1) that the order of acquisition

will be the same as the order found in hearing children (liquid-matter-weight-volume); or that liquid will be the most difficult of the four forms (Oleron and Herren, 1961; Affolter in Piaget, 1966).

The Experiment

Subjects

24 profoundly deaf children (14 boys, 10 girls) from the Illinois School for the Deaf in Jacksonville, Illinois were tested. All of the children had bilateral hearing losses of at least 80db (ISO) in the better ear and had acquired their disability before the age of 2 years. The I.Q. range was from 93-114 with a mean I.Q. of 102. The subjects ranged in age from 7.2 to 12.9 with a mean age of 9.8.

All of the subjects were residential school students who returned home on school vacations, periodic weekends and for the summer. Two of the subjects (a brother and sister) had deaf parents; while the other 22 subjects had hearing parents. Their data, however, was similar to the data of other Ss of the same age group.

Procedure

Each S was tested individually over a Saturday-Sunday period. On Saturday, each S was tested for conservation of liquid and weight and the order of presentation was randomized. Conservation of matter and volume was presented on Sunday with the order again randomized. Each S made a judgment on 3 separate transformations per measure. No prediction questions were asked of the Ss. Following each judgment, S was asked to explain his conservation or non-conservation judgment. The order of presentation of transformations for each form was the same for all Ss.

Tasks

Each S was told on the first day that he/she would be playing some "thinking games."

In the test for conservation of liquid, E used two, 10 ounce drinking glasses each containing 8 ounces of cherry kool-aid. Lines were drawn around each glass to mark the level of the kool-aid. Ss were asked to check [E demonstrated by getting at eye level with the glasses and comparing the level] and agree that the glasses had the same amount of kool-aid. E then poured one glass of kool-aid into a tall, thin beaker and the other glass of kool-aid into a short fat beaker. The two empty glasses were placed next to the new beakers now containing the transformed liquid. In sign language, E said "Now, which one, this one (points to tall, thin beaker) or this one (points to short, fat beaker) has more in (points inside) or do they have the same?" Following S's response, E poured the kool-aid back into the original glasses and asked, "Are they the same?"

After getting S to agree they were the same (there was not one instance where S thought they were variant after the transformation back to the original glasses had been made), E poured kool-aid from one glass into the short, fat beaker. The empty glass was placed beside the fat beaker and S was asked, "Which has more in (points inside the glass and the beaker) or do they have the same?" Following S's response, E poured the liquid from the fat beaker back into the original glass. Again S agreed the two original glasses now containing the liquid were equal. E then poured the kool-aid from one glass into a pear-shaped beaker and the kool-aid from the other glass into the short, fat beaker and posed the same question to S. As in the first 2 transformations, the now-empty glasses were placed beside the beakers which now contained the liquid.

Following each judgment by S, E asked "why do you think that is true?" This constituted the verbal explanation by S of his judgment.

In the conservation of weight problem, E asked S to cut a ball of clay in half. Both halves were weighed separately and E got S to agree they weighed the same. E then instructed S to take one half and make a ball and E would make a pancake. S was then asked, "Which one is heavier?" (E also extended this question by asking which one would make the scale hand move further.) Following S's judgment, both pieces were weighed and S observed they weighed the same. This exact procedure was followed through two more transformations (two halves of the pancake-ball; ball-doughnut).

As in the conservation of liquid problem, S was asked to explain his judgments.

In the conservation of matter problem, E took a ball of clay and asked the S to cut it in half so that both pieces were equal. After E got S to agree that both pieces were equal, S was instructed to make a ball with his half and E made a "bananna." E then asked which had more. Next, E divided the bananna-shaped clay into three pieces and spread them apart approximately 3-4 inches and asked the same question. In the third transformation, the sliced bananna was made into a ball by E and S made a doughnut with the ball-shaped clay. This was followed by a judgment by S regarding which had more.

As in the conservation of liquid and weight problems, S was asked to explain each conservation or non-conservation judgment.

In the conservation of volume problem, a large beaker contained a fixed amount of kool-aid. The fixed level was marked with a blue line around the beaker. Above that blue line was a second blue line. E began by showing S

that when an object was placed in the beaker, the liquid level would rise (to the second blue line). E then showed S a steel fitting (quite obviously heavy) and a piece of clay of identical size and shape. E then asked S "Are they the same height and diameter?" After S agreed that they were the same size, E asked, "If I put this (steel) in the beaker, take it out and put this (clay) in the beaker, which one will cause the kool-aid to rise more or will they be the same?" After S's response, E separately placed each object into the beaker and S observed that in both instances the liquid rose to the second blue line. The clay object was then divided in half and the same procedure followed. Finally, E took a small, hollow fitting into which was placed a ball bearing. Next to it, E placed a larger, but obviously lighter round piece of clay. Again, S was asked to predict the water level.

As in the three previous problems, S was asked to explain his judgments.

Scoring

Each successful conservation judgment was scored a 1; each correct explanation was scored a 1 (S scored a 2 if both were correct); and a 0 was given for an unsuccessful judgment or inadequate verbal explanation. For each S, there was a possible conservation score of 6 points per conservation measure (2 possible points per transformation, 3 transformations per measure); and a total possible score of 24 points (4 conservation measures).

Statistical Analyses

A repeated measures design (split-plot factorial) (Kirk, 1968, p. 248) was used. In order to test for main effects A (age and sex) and B (type of task), two, two-way analyses of variance were used: one with age and one with sex serving as the independent variables and task (conservation) scores as the dependent variable in both analyses.

Results and Discussion

Conservation (B) was marginally significant ($.10 < p < .25$) when both type of sex and age (A) were used as independent variables.

Insert tables 1, 2, 3, 4

Table 5 shows that the order of acquisition of the four forms of conservation was: volume-matter-weight-liquid.

Conservation judgments tended to improve over transformations rather than extinguish: 17 responses showed improvement after a 0 was scored on the first transformation ($T_1 = 0$) vs. 7 responses which showed a decline in performance after a 2 was scored on the first transformation ($T_2 = 2$).

Table 1

Means and Standard Deviations of Age x Conservation Analysis of Variance

		Conservation			
	$\bar{X}$	Liquid	Matter	Weight	Volume
AGE	7.5	$\bar{X}$=0 SD=0	$\bar{X}$=0 SD=0	$\bar{X}$=.17 SD=.40	$\bar{X}$=0 SD=0
	9.2	$\bar{X}$=1.07 SD=1.97	$\bar{X}$=1.37 SD=1.71	$\bar{X}$=1 SD=1.55	$\bar{X}$=1.40 SD=1.74
	10.1	$\bar{X}$=0 SD=0	$\bar{X}$=0 SD=0	$\bar{X}$=0 SD=0	$\bar{X}$=1.40 SD=1.74
	12.5	$\bar{X}$=2 SD=1.79	$\bar{X}$=2.40 SD=2.94	$\bar{X}$=2.40 SD=1.36	$\bar{X}$=3.0 SD=.89

Table 2

Anova Summary Table for Age (independent variable) x Conservation (dependent variable)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F-Ratio
1 A(age)	83.67	p-1=3	27.89	6.73**
2 S_{wg}	82.92	p(n-1)=20	4.146	
3 B(cons.)	6.52	q-1=3	2.172	1.94*
4 AB	6.242	(p-1)(q-1)= 9	.694	.619NS
5 BxS_{wg}	67.28	p(n-1)(q-1)=60	1.121	

*significant beyond the .25 level ($.25 F_{3,69} = 1.41$)

**significant beyond the .01 level ($.01 F_{3,20} = 4.94$)

Table 3

Means and Standard Deviations for Sex x Conservation Analysis of Variance

		Conservation			
		Liquid	Matter	Weight	Volume
S	Male	$\bar{X}$=.43 SD=1.64	$\bar{X}$=.93 SD=1.94	$\bar{X}$=.93 SD=1.54	$\bar{X}$=1.36 SD=1.74
E X	Female	$\bar{X}$=.84 SD=1.90	$\bar{X}$=.96 SD=1.94	$\bar{X}$=.84 SD=1.41	$\bar{X}$=1.6 SD=1.56

Table 4

Anova Summary Table for Sex (independent variable) x Conservation (dependent variable)

	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F-Ratio
1	A(sex)	.1237	p-1=1	.1237	.0171NS
2	S_{wg}	166.461	N-p=23	7.2374	
3	B(cons.)	6.634	q-1=3	2.2113	2.084*
4	AB	.0265	(p-1)(q-1)=3	.0088	.0083NS
5	BxS_{wg}	73.2156	(N-p)(q-1)=69	1.0611	

*significant beyond the .25 level ($.25F_{3,69} = 1.41$)

Insert table 5

Table 6 reveals several interesting behavior characteristics of children who made non-conservation judgments (judged the transformed item and the standard item to be unequal on the relevant dimension).

Insert table 6

Liquid was the most perceptually salient or strongest (79%) and volume the least (31%). Matter (50%) and weight (50%) differed from volume and liquid but not from each other. This order parallels the order of acquisition of the four forms. The inference which seems most reasonable is that the strength of the perceptual cue (height) in the liquid task was sufficient to cause the subject to make a non-conservation judgment regarding quantity. The conservation of volume task on the other hand, did not require the subject to make a judgment after an act (transformation), but rather to predict what would happen to water level when an object was placed in the beaker. This absence of misleading perceptual information may have increased the likelihood that a subject would make a conservation response. 60% of the responses on the volume problem were "no answer" further indicating the perceptual weakness of the task. In summary, the results of Table 6 indicate the degree to which subjects relied on perceptually salient information, and in so doing made non-conservation judgments.

Table 7 shows how subjects responded over transformations.

Insert table 7

Table 5

Differences Among Means of Conservation Forms
(Tukey Method)

		$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$	$\bar{X}_4$
(liquid)	$\bar{X}_1 = 3.10$	-	1.090	1.555	6.205**
(weight)	$\bar{X}_2 = 3.57$		-	.464	5.174**
(matter)	$\bar{X}_3 = 3.77$			-	4.710*
(volume)	$\bar{X}_4 = 5.80$				-

*error term: $\sqrt{MS_{w/n}} = .431$

*significant beyond the .05 level
($.05\ q_{4,20} = 3.462$)

**significant beyond the .01 level
($.01\ q_{4,20} = 5.018$)

Table 6

Type of Response Made by Non-Conservers

Type of Response	Volume	Matter	Weight	Liquid
Judgment based on perceptually-salient cue	31%	50%	50%	79%
Judgment not based on perceptual information	9%	11%	25%	3%
No answer	60%	39%	25%	18%

Table 7

Response of Ss Over Transformations

Score by Transformation			Conservation Forms				
T_1	T_2	T_3	Liquid	Matter	Weight	Volume	Total
0	0	1	1	0	2	0	3
0	0	2	0	0	0	1	1
0	1	1	1	1	0	1	3
0	1	2	0	0	0	1	1
0	2	1	0	0	1	1	2
0	2	2	1	1	2	3	7
						Total:	17
2	0	0	1	0	1	0	2
2	2	0	1	0	0	1	2
2	2	1	1	0	0	0	1
2	2	2	0	2	0	0	2
						Total:	7

General Discussion

The results of the present study did not agree with either Piaget's findings regarding the order of acquisition of the four conservation forms in non-handicapped children or Furth's or Oleron's results based on experiments with deaf children. Instead, there was a developmental reversal of the forms of liquid and volume. This finding, in combination with the behavior of non-conserving subjects (Table 6), provides evidence regarding the high degree to which deaf children are apparently dependent on visual perceptual cues. Because the volume problem did not present a strong, visual-perceptual cue (weight), the deaf subjects were not as "perceptually bound" as they were on the other three measures and consequently were better able to make correct judgments.

As mentioned earlier, Piaget's theory (1967; 1970) states that correct prediction comes before correct judgment in problems of conservation. For example, a child may predict that if one of two identical balls of clay is made into a "sausage" it will still have the same amount as the standard ball. However, when the experimenter makes the actual transformation, the same subject may, in the presence of 2 arrays of different dimensions, change his mind and make a non-conservation response. In the conservation problems of liquid, matter and weight, the Ss made judgments after comparing two dissimilar (but equal in amount) items. However, in the conservation of volume problem, subjects were presented with two dissimilar items (but equal in quantity) and instructed to predict which would displace more water. This task dissimilarity, in addition to the fact that the volume problem was always presented on the last day, may be confounding the results. Alert subjects could learn that transformations made on the previous day had no effect on the items to the extent that the correct answer was always

"the same". The results of Table 7 could be interpreted as additional evidence that learning was taking place (subjects who made non-conservation responses on the first transformation tended to improve their judgments after three transformations). However, another reasonable interpretation of the data in Table 7 is that while conservation was present, it did not manifest itself until sufficient probing took place.

While the possibility of confounding in the volume task is present, it should not be taken as an absolute certainty. The procedures used in this study were quite similar to the procedures used by other experimenters. Elkind (1961a) always presented volume last and it proved to be the most difficult for his subjects. However, Elkind limited his transformations to one per conservation measure and thus reduced the amount of information the subject could learn and which could help with the eventual "solution" of the volume problem. Also, prior to this study, these conservation problems were presented to five hearing children between the ages of 5.11-10.9 years using the same procedure and always presenting the volume problem last. In this "trial test," conservation of volume was considerably more difficult than the other three forms (the order of acquisition was liquid-matter-weight-volume; although volume was the only form which was measurable different).

Piaget (1967; 1970) argues that a quantity is difficult to conceptualize, and so to conserve, to the degree that it is associated with the subject's own actions. Weight, the misleading cue in the volume problem, is more closely tied to the child's action than length or height, the perceptual cues which bind non-conservers on the other problems. However, for deaf children, it seems that the absence of visual perceptual information makes their judgments on the volume problem more accurate.

Finally, a problem which has manifested itself in conservation experiments with hearing children and is most likely even more dramatic in administering cognitive tasks to deaf children is the linguistic aspect of the procedure (Gelman, 1972; McGarrigle and Donaldson, 1975). Gelman (1972) states that conservation is present in young children earlier than Piaget concedes and that the reason it appears to be absent is because of extra-logical difficulty: children do not understand the key words more and less. McGarrigle and Donaldson (1975) also feel that traditional procedures may underestimate children's cognitive abilities in that characteristics of the experimenter's actions toward the task materials can influence children's interpretation of utterances by suggesting the experimenter is thinking about a different attribute from that specified linguistically. In a conservation problem, for example, when the experimenter asks the subject to predict whether an item will have more or less after it is deformed, then makes the deformation and again asks the question regarding more or less, this non-verbal behavior by the experimenter (carrying out the transformation) may influence the interpretation the subject now places on more and less.

Results of prior studies indicate that either through pre-experimental training on the key linguistic terms (Gelman, 1972) or by substituting a teddy bear for the experimenter to carry out the transformation and make it appear to be an "accident" which was disassociated from the experimenter's actions (McGarrigle and Donaldson, 1975), conservation performance significantly improved.

Summary

Twenty-four profoundly deaf children from a residential school were presented with conservation problems of liquid, matter, weight and volume. Analyses of variance showed that age was significant beyond the .01 level and type of task (conservation) at the .25 level. No significant sex effect was found. Differences among means were computed and suggested the following order of acquisiton: volume-matter-weight-liquid.

This order was in disagreement with the order established by Piaget with non-handicapped children; and, in regard to volume, significantly different from the order established by Affolter (see Piaget, 1966) with deaf children. The developmental reversal of both liquid and volume, the two forms which are acquired approximately five years apart in hearing children, seriously weakens Furth's position that deaf and hearing children do not essentially differ regarding cognitive development and his argument regarding the relationship of language and cognition during the concrete operational stage of development.

Additional research is needed to determine the reliability of this new order of acquisition. Such a study should counterbalance the order of presentation and use a control group of hearing children matched with the deaf subjects on age. Additionally, such a study should be designed based on the assumption that conservation problems test for the child's logical capacity to treat quantity as invariant. Consequently, extralogical difficulty, e.g., the language aspect of the procedure or the experimenter's potential bias must be minimized.

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